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Implementing effective group work for mathematical understanding in primary school classrooms in Hong Kong*

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Abstract

The Hong Kong Education Bureau recommends that primary school pupils' mathematical achievement be enhanced via collaborative discussions engendered by group work. This pedagogic change may be hindered by Confucian heritage classroom practices and Western-dominated group work approaches that predominate in Hong Kong. To overcome these obstacles, we introduced a relational approach to group work in a quasi-experimental study. Our sample included 20 teachers randomly allocated to experimental (12) and control (8) conditions and their 504 mathematics pupils (aged 9-10). The relational approach focused on the development of peer relationships in a culturally appropriate manner and was implemented over seven months. Pupils were pre-/post-tested for mathematical achievement and systematically observed, and the teachers were assessed for subject knowledge and pre-/post-tested for pedagogic efficacy. ANCOVA and HLM results show enhanced mathematical achievement, supported by improved peer-based communication skills and time-on-task for the experimental pupils. Experimental teachers raised their pedagogic efficacy. Results indicate the potential of the relational approach for boosting academic achievement via enhanced child-peer-teacher interaction and the need to reassess the role of peer-based latent collectivist learning in Confucian heritage classrooms.

Introduction

International comparisons consistently show schoolchildren in Hong Kong (HK) to exhibit high levels of mathematical achievement (Mullis, Martin, Foy, & Arora, 2012; Organization for Economic Cooperation and Development [OECD], 2010). Among the explanations for their superior achievement is the Confucian heritage culture (CHC) that prevails in HK classrooms, which is exemplified by strong teacher direction and pupil conformity to competitive classroom norms (Biggs, 1996; Li & Wegerif, 2014). At the same time, however, HK has implemented a range of curriculum reforms designed to discourage traditional didactic teaching and enhance pupils' learning engagement through peer-based discussions as part of classroom group work (Curriculum Development Council Hong Kong [CDCHK], 2001). Underlying these reforms is the expectation that group work allows pupils to take collaborative responsibility for learning tasks (Howe, 2010; Slavin, 2013) that draw on elaborated explanations to enhance their understanding and correct misconceptions (Webb et al., 2014). The inclusion of group work and collaborative discussion in the HK curriculum mirrors Western curriculum reforms in which innovative pedagogies such as cooperative and collaborative learning are used to encourage pupils' mathematical engagement (Slavin & Lake,

2008; Department for Children, Schools & Families [DCSF], 2009; Department for Education [DfE], 2013). However, introducing group work to the mathematics classroom is sometimes considered problematic, as it is contrary to traditional mathematics pedagogy whereby students are taught in an individualistic manner (Webb et al., 2014). Thus, the simple proposal that group work should be integrated into the mathematics curriculum does not necessarily mean that this alternative pedagogic approach will positively affect pupils' mathematical achievement.

Group Work and Mathematics Learning: Western Perspectives

Reviews of group work in Western primary school classrooms (Gillies, 2012; Kutnick & Blatchford, 2014; Reznitskaya et al., 2009; Roseth et al., 2006) attest to the relevance of group-based learning for children's academic achievement and cognitive and social development. These reviews note the existence of various approaches to encouraging children to work together to enhance learning (e.g., group work, cooperative learning, collaborative learning, team work), although some approaches are not consistently effective for all children. Effective grouping requires more than simply seating children around a table (Galton, Hargreaves, Comber, Wall, & Pell, 1999), assigning them undifferentiated tasks with no accountability (Stein, Grover & Henningsen, 1996) or expecting that they will naturally draw upon cognitive-based explanations and justifications when they share ideas with one another (Emmer & Gerwels, 2002; Webb et al., 2014).

The main types of classroom group work studies can be described as atheoretical naturalistic grouping or theoretically structured grouping to promote cooperative or collaborative learning. The effectiveness of these broad approaches varies owing to a range of whole-class inclusion, methodological and theoretical issues. Naturalistic grouping does not differentiate between the types of learning activities assigned to groups, and is associated primarily with table-based seating (Galton et al., 1999; Kutnick & Blatchford, 2014). Within the naturalistic approach, there is little evidence that teachers design tasks that

allow/encourage pupils to act interdependently or that pupils have the desire or skills to communicate with and support one another (Mercer & Littleton, 2007; Stein et al., 1996; Webb et al., 2014). Theoretically based group work emphasizes inclusiveness (Roseth, Fang, Johnson & Johnson, 2006; Slavin, 2013), stressing that heterogeneous small groups can overcome status and stereotypical preferences to result in some form of cooperation or collaboration. Historically, theoretical approaches draw on developmental (from Piaget, 1971 or Vygotsky, 1978) or social (Deutsch, 1949) psychological theory. All approaches assume that children have the skills and desire to undertake tasks with their peers.

Different theoretical bases have been associated with various classroom-based approaches that differentiate between learning tasks, communication skills and interpersonal grouping contexts. The best known group work approaches are dominated by cooperative and collaborative learning. Cooperative learning allows individuals to work together toward a specific learning goal (Panitz, 1997), with each group member usually assigned a unique sub-task to enable all group members to progress toward the group goal (Dillenbourg, Baker, Blaye, & O'Malley, 1996; Slavin, 2013). Cooperative learning is based on theories of interdependence and contact (Deutsch, 1949; Slavin, 2013). This task-/positional-oriented approach is noted for enhancing learning and peer relationships in classrooms. Reviews of cooperative learning (Roseth et al., 2006; Slavin, 2013) have documented it to exert small but positive achievement effects in groups, particularly in mathematics (Davidson & Kroll, 1991; Slavin, 2013). However, Barron (2003) and Kutnick and Blatchford (2014) argue that most cooperative study is short-term and requires children to undergo training for interdependent learning (Roseth et al., 2006). Recent randomized controlled studies (e.g., Slavin et al., 2013) have found no significant difference in mathematics achievement between cooperative and traditional teaching approaches over a one-year implementation period.

Collaborative learning “involves the mutual engagement of participants in a coordinated

effort to solve problems” (Dillenbourg et al., 1996, p.190; also Howe, 2010; Mercer & Littleton, 2007; Webb et al., 2014; Yackel, Cobb, & Wood, 1991). It requires that pupils engage in elaborated/explanatory dialogue although studies of such learning will depend on children’s cultural and personal histories (Barron, 2003) that do not necessarily prioritize inclusion. Collaborative learning studies undertaken within mathematics tend to focus on children’s use of communication skills while they engage in joint problem-solving (Webb et al., 2014; Yackel et al., 1991). Those communication skills include various forms of elaborated speech (explaining, justifying, etc.) undertaken in a supportive manner, and are rare in traditional classrooms (Mercer & Littleton, 2007; Webb et al., 2014). Further, when communication skills are taught in the traditional classroom, not all children will develop them to the same degree (Reznitskaya et al., 2009). One of the few meta-analyses comparing the collaborative approach with the traditional classroom approach (The Metiri Group, 2009) identified only limited collaborative learning effects. Thus, although the cooperative and collaborative learning approaches have strong theoretical underpinnings, controlled comparative studies of the two have identified few differences in outcomes from studies of naturalistic pupil grouping.

Researchers working in a number of Western countries, including Australia, Israel, the U.S. and the U.K., have raised questions concerning the limited pedagogic and achievement effects documented for group work in mathematics classrooms. Slavin et al. (2013) and Stein et al. (1996) identified differences in effects between pupils sitting in groups naturalistically and pupil grouping for which there was a clear theoretical basis. Theoretically based grouping must account for within-class engagement processes aligned to cooperative sharing and collaborative communication within the group (Kramarski & Mevarech, 2003; Webb et al., 2014). Slavin et al. (2013) also noted that group work effectiveness is associated with teacher ownership of the pedagogy. Nevertheless, pupils are often placed in groups within the classroom without effective within-group working strategies (Kutnick & Blatchford, 2014).

In their review of classroom group work and the mathematics curriculum, Slavin and Lake (2008) argued that boosting mathematics achievement often requires more than a cooperative approach. Pupils should be able to draw upon explanations and reasoning skills with the help of their teachers and peers (Kramarski & Mevarech, 2003; Webb et al., 2014). Teachers also need to be trained and to accept the principles of group work, including the structuring of group goals and individual accountability in classroom-based mathematical activities (Slavin et al., 2013). This review of group work approaches acknowledges the inconsistent results regarding children's mathematics achievement to date, which may be explained by the lack of theoretical bases for group work or the misuse of or shortcomings within current theories.

HK Classrooms: Confucian Heritage Context and Group Work in Mathematics

As noted, HK consistently scores highly in international comparisons of pupils' mathematics achievement, although scores have dipped slightly in recent years (Mullis et al., 2012). To facilitate higher levels of pupil achievement, the HK Education Bureau (EDB) launched a program to reduce class sizes in primary schools (EDB, 2008), and is advocating changes in pedagogic approach that include increased pupil engagement via discussions within group work (CDCHK, 2001). Galton and Pell (2010) have confirmed that class sizes have been reduced, and other HK-based researchers (Fung, 2014; Mok & Morris, 2001) have identified progress toward the implementation of group work to enhance pupil engagement. However, these researchers do not identify the type of group work implemented nor discuss whether participation in such work has enhanced pupils' mathematical achievement. Further, Galton and Pell (2010) found class size reduction led to changes in teachers' pedagogic approach only infrequently and to exert little effect on pupils' mathematics performance.

Although the ongoing curricular reforms in HK recommend engaged learning via discussion and communicative group work, that recommendation is made within an education system that is portrayed by many as traditional, examination-oriented and competitive (Biggs,

1996; Li, 2003). Under the influence of the prevailing CHC, teachers usually maintain control through didactic teaching, particularly in mathematics lessons (Li, 2003; Mok & Morris, 2001). A review of the literature on CHC, however, provides a number of contradictory views on its application in the classroom. A simplistic view of CHC sees the learner as passive, reluctant to express opinions and respectful of the teacher and his or her authoritative knowledge (Mok & Morris, 2001); as preferring concrete knowledge and structured, non-reflective learning (Biggs, 1996; Hofstede & Hofstede, 2005); and as individualistic and reluctant to participate in group discussions (Tang & Williams, 2000). This picture of rote learning, memorization, learner passivity and teacher virtuosity (Kennedy 2010; Mok & Morris, 2001) leaves little room for group work within highly structured CHC classrooms (Liu, 2002; Nguyen, Terlouw, & Pilot, 2006). Further, given that CHC classes tend to be large (30+ pupils) with short lesson periods (35 minutes) with pupils seated at individual, teacher-focused desks (Fung, 2014; Galton & Pell, 2010), they appear to present the antithesis of current curriculum expectations regarding learner engagement via group work.

However, the evidence for this simplistic view of CHC and for the notion that it does not support group work in HK may not be as strong as previously thought. Two decades ago, Biggs (1996), in contrast to the prevailing view, described HK classrooms as student- rather than teacher-centered. Other researchers argue that HK teachers try to encourage high levels of cognitive understanding in all of their pupils (e.g., Li, 2003), and HK pupils have been described as having the potential to be active, open and reflective (Cheng, 2000). Also, if allowed to work in groups, pupils have been found to engage in critical analysis (Tang, 1996). Pupils' ability to engage in group work within HK CHC classrooms may be explained by a combination of children's respect for their teachers and willingness to adapt to diverse pedagogic methods that are legitimized by their teachers (Flowerdew, 1998; Kennedy, 2010; Nguyen et al., 2006) and their tendency to collectively review and share classroom-based

information informally outside the classroom (Biggs, 1996; Tang, 1996). Thus, pupils can draw upon their ability to communicate with one another supportively within a classroom context that allows for group rather than individual seating. For group-based learning to be effective, however, it is also important that teachers, too, are supportive of it (Fung, 2014). If an effective group work program is to be implemented in HK classrooms: (i) teachers should provide legitimacy for non-traditional pedagogic practices; (ii) the physical layout and curricular practices need to be adapted for group learning tasks and peer interaction; and (iii) pupils' informal collectivistic orientation should be incorporated into classroom learning. Although these recommendations are not unique to HK (Baines et al., 2009; Slavin et al., 2013), it is important that group work be implemented via a culturally appropriate pedagogy (Whitty, Power, & Halpin, 1998). The aforementioned recommendations also acknowledge that HK teachers still maintain a traditional pedagogic approach (Galton & Pell, 2010); that teachers and pupils require a form of group work that is more complex than that seen in naturalistic grouping studies (Kutnick & Blatchford, 2014); and that Western-based cooperative and collaborative approaches to group work may not be appropriate for use in the CHC classrooms of HK (Nguyen et al., 2006; Whitty et al., 1998).

Identifying the Research Problem

At this point, readers may be wondering (i) why teachers in HK should persist with a group-based approach to enhance pupils' understanding and achievement in mathematics and (ii) whether an alternative approach to group work may prove more effective in the mathematics arena than the cooperative, collaborative and naturalistic learning approaches reviewed above. Before considering possible alternative approaches, two qualifications must be raised concerning the effective use of group work for enhanced learning. First, all of the group work studies considered, whether they examine the cooperative, collaborative or naturalistic approaches, assume that pupils want to undertake learning tasks together. They fail to

problematize the issue or note that there must be positive relationships among the pupils in a class before the teacher can expect them to work on learning tasks with their peers. The skills most often cited as enhancing learning via group work are the ability to share perspectives and use elaborated speech (Howe, 2010; Mercer & Littleton, 2007; Yackel et al., 1991). A logical step in introducing group work is to ensure that all pupils in the class are capable of developing positive relationships with their peers, that is, to adopt a relational approach. The relational approach differs from the naturalistic, cooperative and collaborative approaches in two ways. First, it draws upon the developmental/social psychology of close relationships (Kutnick & Blatchford, 2014) rather than upon interdependence/accountability (Roseth et al., 2006; Slavin, 2013). Then, once a relational foundation is in place in the classroom, pupils are in a position to work collaboratively and to jointly draw upon supportive elaborated speech (including explanations, questions, information provision and agreement; see Mercer & Littleton, 2007; Webb et al., 2014; Yackel et al., 1991). Second, any effective group work approach needs to draw upon culturally appropriate pedagogy. As already noted, Nguyen et al. (2006) argue that Western-based cooperative/collaborative approaches are likely to clash with CHC classrooms because of differences in power/authority distributions. A culturally appropriate group work pedagogy for CHC classrooms require teachers to legitimize and support group skills, establish classroom conditions that facilitate group work and pupils' informal collective learning support.

Effective group work in this context also requires positive inter-pupil relationships (Kutnick & Blatchford, 2014). Approaches based solely on the Western experience appear to have a number of inherent problems (Kutnick & Blatchford, 2014; Slavin et al., 2013), with the exception of one quasi-experimental program that has provided consistent positive achievement /cognitive development outcomes in a number of cultures. That program, called Social Pedagogic Research into Group Work (SPRinG; Kutnick & Blatchford, 2014), contrasts with

previous group work programs in that it provides strong support for the relational development of all pupils (inclusively) in the classroom; was developed with strong reliance on teachers' cultural and classroom knowledge; requires an adaptable classroom and curriculum context that allows for group working; and has a lengthy implementation period (Baines et al., 2009). Perhaps its most distinctive aspect is SPRinG's focus on developing children's inclusive relational skills. In problematizing peer-based relationships (see below), interpersonal support and communication skills are developed among all pupils. These communication skills underlie elaborated discussions that enhance cognitive reasoning and explanation (which are usually taught directly as separate social skills in cooperative /collaborative approaches; see Gillies, 2012; Kramarski & Mevarech, 2003; Webb et al., 2014). SPRinG studies have been undertaken in England, Scotland and several Caribbean countries (Kutnick & Blatchford, 2014). The findings of these studies provide consistent evidence of teachers' ability to move from a traditional controlling curriculum and knowledge orientation to a stance of observing and monitoring their pupils and of increased teacher confidence in offering group work opportunities to pupils, although there was between-teacher variation in the extent to which the approach was adopted. In addition, children at all attainment levels benefited academically compared with their counterparts in the control classes.

Research Questions

The HK government encourages alternatives to traditional CHC mathematics teaching (CDCHK, 2001; Cai & Ni, 2011), but there is limited evidence in classrooms of a pedagogical shift from the traditional CHC paradigm to approaches that enhance group work (Fung, 2014; Galton & Pell, 2010). If a pedagogic shift that affects pupils' achievement is detected as a result of an experimental intervention, the study in question must account for teachers' initial level of subject knowledge and pedagogic efficacy (confidence in teaching the topic), as well as how they support group work and pupils' development of communication skills in their classrooms.

Accordingly, the study reported herein was guided by the three following research questions:

- (i) Can a relation-based group work approach be adapted/co-developed by HK primary school mathematics teachers and successfully applied in their classrooms?
- (ii) Does the developed group work approach affect teachers' actions and interactions in the classroom over time?
- (iii) Are children's discussion skills and corresponding level of mathematical achievement enhanced by active participation in group work steered by the given approach over time and in comparison with matched controls?

Methods

Research Design

The use of a quasi-experimental research design allowed the (whole class) teaching unit to continue in an authentic and ecologically valid manner (Wegener & Blankenship, 2007) without imposing new organizational processes that would be necessitated by a randomized, controlled design. Quasi-experimental research requires the classroom background of the experimental and control classes to be equivalent, and thus we initially ascertained whether the mathematics teachers had similar backgrounds and levels of mathematical subject knowledge and whether the pupils had similar levels of mathematical achievement. Given that HK has a standard primary school mathematics curriculum, it was assumed that all of the teachers (classes) involved in the study would be teaching (be taught) the same mathematics topics at roughly the same time over the course of the study. Implementation/testing took place between December 2013 and July 2014, accounting for approximately 80% of the school year. To match the experimental and control classes, each of the 10 participating schools was asked to identify two P4 mathematics teachers (P4 pupils are aged 9-10) who taught classes of similar attainment levels. These teachers were then assessed in terms of teaching experience and mathematical subject knowledge prior to study commencement and pre-/post-tested for mathematical pedagogic efficacy. In addition, their implementation of

group work was assessed via classroom observations throughout the study period. Their pupils were pre-/post-tested for their degree of age-appropriate mathematical achievement, and target pupils' communicative actions, interactions and engagement in learning tasks during group work were observed. Ethical approval was gained from the host university, and the participating schools, teachers and parents of the children involved provided informed consent.

Sample

Teachers. Twenty mathematics teachers (10 women and 10 men), two from each school, participated in the study. All teachers expressed an interest in enhancing their pupils' mathematical achievement. Nine teachers had studied mathematics to the Bachelor's degree level, seven to age 18 and two to age 16. The teachers were randomly allocated to experimental and control groups, aiming to have one experimental and one control teacher per school (similar to large-scale mathematics/group work studies; e.g., Slavin et al., 2013).

Pupils. Five hundred and four pupils of the 20 P4 mathematics teachers participated. Class sizes ranged between 14 and 33 pupils (excluding one special education needs class with eight pupils), for an average class size of 26.11.

Relational Approach

The relational approach was co-developed with the participating teachers based on an original design (Kutnick & Blatchford, 2014). Drawing upon a psychological model of close relational and social development, the approach follows a sequence of whole-class, inclusive activities designed to enhance children's trust/security/support in working with one another (Wentzel, 1991), leading to effective communication (listening, explaining, sharing; Gillies, 2012) and joint problem-solving (Dillenbourg et al., 1996). Once pupils have undergone classroom training in the approach, the support, communication and joint problem-solving skills that they co-develop can be applied to a range of primary curriculum subjects,

including literacy, science, social studies and, in the present study, mathematics. To encourage classroom inclusion, children are asked to change partners periodically and not to undertake the training with pre-existing friends (Baines et al., 2009). As noted in previous relational approach studies, the role of the teacher is vital in legitimizing relational activities in the classroom. Higher levels of teacher involvement have been associated with higher levels of pupil progress, affording teacher “ownership” of the approach within the classroom (Baines, 2014). Teachers also base that ownership on classroom cultural knowledge such that relational skills and associated adaptations in the classroom are undertaken via a culturally appropriate pedagogy. Thus, the role of teachers, classroom layout and curriculum tasks are coordinated with pupils’ developing relational skills (Baines et al., 2009). When the approach is applied in experimental classrooms, researchers expect to observe changes in teacher and pupil behavior similar to those in the classroom described by Yackel et al. (1991). Teachers do not change their curriculum sequence, but allow for a higher level of pupil-based developmental problem-solving through small group discussions. In contrast to Yackel et al. (1991), the development of discussion skills in this study was based on trust/communication skills structured into the relational approach, allowing us to assess the effects on pupil achievement in the experimental and control classes over time. Both sets of classes maintained their usual curriculum sequence, with the control teachers expected to retain a more didactic teaching approach with fewer group working opportunities for their pupils.

Between December and May of the academic year, the experimental teachers were provided with two full-day and three evening training sessions in the relational approach. The control teachers were provided with an equivalent amount of time for pedagogic development, with the amount and type of training determined by the teachers individually. Information on the type or extent of training undertaken by the control teachers was not collected, although all of the participating teachers expressed interest in enhancing their pupils’ mathematics

achievement. Following the classroom observations (see below), the experimental teachers were provided with feedback on their use of the relational approach, whereas their control counterparts received general feedback on the type and quality of the interactions in their classrooms. All of the teachers used some form of group work during the school year.

Instruments

Before each of the following instruments was employed, their ecological and content validity for use in P4 classrooms was assessed on non-sample, age-appropriate teachers and their classes in HK.

Pre-testing. The teachers were assessed for subject knowledge and pedagogic efficacy in mathematics and for group work implementation. (i) Mathematics subject knowledge (SMK) was assessed by a survey developed in the UK and adapted for HK by Tsang and Rowland (2005), it included 16 items (scored on 5-point scales on which 1 represents an incorrect answer with no explanation and 5 represents a correct answer with an explanation) covering “themes of basic arithmetic competence, mathematical exploration and justification, and geometric knowledge. These three themes were chosen because they [are] basic elements of the HK mathematics curriculum and they address both substantive and syntactic knowledge of mathematics” (Tsang & Rowland, 2005, p. 4). (ii) The pedagogic efficacy (PEf) scale asked teachers to rate (on 5-point scales on which 1 represents “I hate teaching this, and pupils find it difficult” and 5 represents “I love teaching this, and pupils get it”) their personal teaching efficacy and ability to promote pupil engagement with regard to 19 age-appropriate mathematics teaching topics for P4 classes (e.g., place value, addition/subtraction, fractions/decimals). (iii) Group work implementation in the classroom used 5-point reflective scales (see Kutnick & Blatchford, 2014), its items included learning context (e.g., flexible seating, toys/games that can be used by more than one child); activities/tasks/resources conducive to sharing (e.g., children asked to undertake activities in small groups, encouraged to talk with their peers);

teacher encouragement for children to work together (e.g., provision of briefing/debriefing on collaboration); teacher provision of child training in peer relational support (e.g., trust, communication, problem-solving skills); child engagement in peer-based interactions (e.g., sharing dialogue, joint problem-solving); child engagement in relational activities (e.g., discussions and support for peers); and general reflection on how well the teacher had prepared the class for group work. All of the researchers were trained in using the rating scales and reaching agreement in the case of inter-rater discrepancies. The instruments were found to be highly reliable: SMK survey: $\alpha = 0.84$; PEF: $\alpha = 0.95$; implementation pre-/post-test: kappa = 0.87/0.90. (iv) Additional information was collected from the teachers concerning their number of years of teaching experience and the highest level of mathematics education they had attained.

Teacher-pupil actions and interactions were systematically observed by trained researchers using a scheme developed by Blatchford (2003). The systematic observations focused on six target children per class (representing high, middle and low mathematics achievers along with the pupils sitting next to them). Observations were carried out during the working part of the lesson, after the introduction and before the final plenary session. During the observations, the researchers identified the work setting (individual, small group, whole class), communicative behavior with peers and the teacher (listening, non-verbal communication, questioning, explaining, suggesting, giving information, agreeing), and task engagement (on- and off-task). Each target was observed for 20 seconds, with the observer then recording which actions and interactions characterized that period. Each target was observed eight times per classroom observation session. To ensure reliable observations, each observer underwent training in the use of the observation schedule, allowing the researchers to define, discuss and agree upon categories before the classroom observations began. It was not possible to calculate the inter-rater reliability within the actual classroom observations

because the observers were assigned to watch/rate different target children, and secondary observers would have been intrusive.

The pupils were assessed using the following instruments. (i) Their mathematics attainment was assessed by their score on an adapted and validated government-designed mathematics assessment for P3. The test's 38 items cover simple and complex multiplication and division, geometry, number order and charts. The test is highly reliable ($\alpha = 0.85$).

Post-testing. Post-test data were collected toward the end of the school year, with care taken to avoid periods of within-school and territory-wide testing. The instruments used were, in the main, the same as those used for the pre-tests. *The teachers* were reassessed in terms of (i) PEF and (ii) group work implementation, *teacher-pupil* actions and interactions via systematic observations and *the pupils* were reassessed for mathematics attainment (using an adapted, validated government-designed assessment for P4 with 36 items similar to the P3 test, but with the addition of fractions, decimals, area and symmetry; the test is highly reliable [$\alpha = 0.87$]).

Statistical Analyses

Given the sample size and range of comparisons, a two-stage approach to data analysis was adopted. The initial stage was descriptive: assessing the (i) pre-test and (ii) post-test differences between the experimental and control teachers and their classes. Where possible, pre-test data were used as a covariate in the latter assessment. Parametric and non-parametric analyses appropriate to the level of the measure were used. It should be noted that the pupils' P3 and P4 mathematics attainment tests covered similar items, although the actual questions differed. Hence, no direct item-to-item comparisons could be made, and the difference in pupil scores over time was based on analysis of covariance (ANCOVA). In the second stage, hierarchical linear modeling (HLM) was deemed possible (Raudenbush & Bryk, 2002), as the individual pupil achievement scores were nested in pupils' classrooms (hence, the two levels of individual and class). When performing HLM, a composite score for collaborative

interaction was calculated (comprising questioning, explaining, suggesting and time on-task; individual scores were highly correlated) to assess the interaction with pupils' co-varied P4 mathematics attainment scores. Data from the children in the small (experimental) special education needs class were excluded.

Results

Descriptive: Pre-test Comparisons

The experimental and control teachers and pupils were closely matched (see Table 1). There was no significant difference between the two teacher groups in their level of mathematics education, amount of classroom teaching experience, mathematical subject knowledge (as measured by the SMK survey) or pedagogic efficacy (PEf). Although the difference did not reach significance, it should be noted that the control teachers had more teaching experience (approximately 3 extra years) and higher PEf scores (an average of 10 points). The experimental and control classes had similar boy-to-girl ratios, although the control classes had significantly fewer pupils overall. No statistically significant differences in P3 mathematics achievement were found between the two sets of pupils.

Table 1
Pre-Test Matching of Experimental and Control Groups: Teachers, Pupils and Classes
(standard deviations or percentages of pupil characteristics in brackets)

CATEGORY OF COMPARISON	Exp. means	Control means	Difference
Teacher Categories	12 teachers	8 teachers	
Level of mathematics education+	2.42	2.50	N.S.
Years of teaching experience	9.17 (5.86)	12.13 (9.39)	N.S.
SMK	50.17 (11.65)	49.38 (9.74)	N.S.
PEf	52.08 (21.88)	62.63 (14.67)	N.S.
Pupil Categories			
Pupil numbers and sex ratios	319	185	
Males	193 (60.5%)	111 (60.5%)	N.S.
Females	126 (39.5%)	73 (39.5%)	
P3 mathematics assessment	71.79 (15.52)	72.12 (15.52)	N.S.
Class Categories			
Class size++	28.27 (4.54)	23.13 (4.73)	F(1,17) = 5.747*
Implementation rating scale	14.29 (2.16)	7.59 (4.29)	F(1,42) = 41.972***

+ From an ordinal measure indicating that most teachers studied mathematics beyond age 18.

++ Class size excludes the experimental special educational needs class of 8 pupils.

*p < 0.05; **p < 0.01; ***p < 0.001

Research Questions 1 and 2

The first and second research questions focus on development and change in the experimental teachers over the course of the implementation period. The experimental and control teachers began the study with similar teaching backgrounds and degrees of SMK and Pef. Within the first systematic observation period, the experimental teachers were more likely to configure their classrooms for group work than the control teachers ($X^2[2] = 135.45$, $p < 0.001$), with 70% of the observations in these teachers' classrooms documenting a setting conducive to group work compared to 26% in the control classrooms. The end-of-year observations witnessed slightly more group work settings in both, although the difference between the experimental and control classes was similar ($X^2[2] = 114.55$, $p < 0.001$). A group setting was observed in 73% and 31% of the experimental and control class observations, respectively, although a group setting is not necessarily associated with enhanced achievement. However, even limited early intervention training in group work was found to support greater use of group work by the experimental teachers.

Unsurprisingly, the relational approach to group work was more common in the experimental classes. With regard to the group work implementation scales, the experimental teachers immediately employed the relational approach and group work and maintained their use, and over the year these teachers increased their total scores (from 14.29 to 15.08). The control teachers, in contrast, saw a decrease in their total scores (from 7.59 to 7.06). Table 2 with the associated ANCOVAs per scale shows that the experimental teachers and classes increased in the pre- to post-scales with regard to learning context, teacher encouragement for children to work with together, child engagement in interactions, and child engagement in relational activities and decreases in activities/tasks conducive to sharing and teacher provision of child training in peer relational support. The scale increases for the experimental teachers/classes indicate their greater familiarity with and use of group work skills while

undertaking mathematics learning tasks relative to the controls, whereas the scale decreases indicate that group work training was no longer required toward the end of the school year.

The control teachers showed only small increases in learning context and activities/tasks conducive to sharing, and demonstrated consistently low levels of development and support for group work. Learning context was the only scale for which the ANCOVA results indicated no significant difference between the experimental and control classrooms, indicating that both had physical set-ups conducive to group work.

Table 2

Means and Differences between Experimental and Control Teachers with Regard to Group Work Implementation Scales over Time (scale: 0-4)

SCALES	Initial Observation		Final Observation		ANCOVA (F)
	Experimental	Control	Experimental	Control	
Learning context	2.52	1.82	2.96	2.00	2.30
Activities/tasks conducive to sharing	2.78	1.18	2.60	1.25	3.08*
Teacher encourages pupils to work together	1.78	0.71	2.04	0.63	10.03**
Teacher training for relational support	1.37	0.59	0.48	0.13	4.15*
Child engagement in peer-based interactions	2.00	1.12	2.44	0.94	11.13**
Child engagement in relational activities	1.85	1.06	2.28	1.00	5.52*
Overall preparation for group work	2.00	1.12	2.20	1.13	7.50**

* $p < 0.05$; ** $p < 0.01$

In line with the foregoing implementation differences, the experimental teachers also saw improvements in PEF. The pre-test PEF scores were higher for the control teachers, whereas in the post-test the experimental teachers out-scored the control teachers (67.00 versus 66.00). This change was significant for the experimental teachers (the post-test regression co-varied by the pre-test scores was statistically significant: $F[3,16] = 5.47$, $p < 0.009$).

Overall, the experimental teachers were found more likely to use group settings and to implement aspects of relational group work in their classroom pedagogy than the control teachers. Use of the relational approach was also associated with an increase in the

experimental teachers' PEF scores, which is indicative of their greater enjoyment of teaching age-appropriate mathematics topics and of greater learning engagement by their pupils relative to the controls. This is not to say that the control teachers refrained entirely from the use of group work and relational approaches. In fact, these teachers used group work in approximately 30% of their final observation lessons. However, within these lessons only limited use of relational aspects was observed in their pedagogic approach, and no increase in PEF was seen over time.

Research Question 3

The third research question focuses on the enhancement of pupils' mathematical achievement over time and on taking into account changes in interpersonal discussion skills that may explain that enhanced achievement. The post-test scores were significantly higher for the experimental pupils (62.43 [sd = 15.60]) than the control pupils (59.09 [sd = 17.83]) when compared by ANCOVA ($F[1, 479] = 9.72, p < 0.002, d = 0.202$). While the post-test showed gross mathematical differences between experimental and control pupils, researchers were able to identify a number of curriculum-based mathematical concepts that had been reviewed in training sessions with experimental teachers, taught in all classes and where experimental pupils scored significantly higher ($p > 0.001$) than control pupils. These concepts included fractions, lowest common multiple/highest common factor, equivalence, number order, patterns, area and perimeter. Associated with these differences in mathematical achievement were changes in the experimental pupils' communication and group work skills. For example, Figures 1 and 2 illustrated how the experimental teachers designed different group work activities related to the teaching of fractions and area in the training sessions. It is considered that they can inform the differences in the mathematical achievement of the experimental students regarding some post-test mathematics items, such as that shown in Figures 3 and 4.

Figures 1 through 4

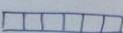

Pupil classroom tasks regarding fractions and area (figures 1 and 2) with related P4 test questions (figures 3 and 4)

Figure 1

Comparing Fractions

- ① Same denominator, different numerators.
numerator \uparrow , value \uparrow
- ② Same numerator, different denominators
- ③ Comparing the values of 3 Fractions
(①+②)

Steps: 1. Give each group different materials

- a group with some squares  on a paper
- a group with circles on a paper 
- a group with some paper stripes

2. Groups with squares & circles will colour the shapes according to the fraction given

Groups with stripes will fold them and shade the parts according to the fraction.

3 Report & Present *De Brief*

4. Draw conclusion

Figure 2

長方形及正方形的面積 (Area)

• 4人一组 • Task (比較長方形的大小+利用正方形, 格子)

Step 1: Count the ~~grid~~ squares. \rightarrow compare

Step 2: ~~The~~ The relation of the (area) with the length and the width of the rectangle


Step 3: Draw a rectangle with the constraint: of area must be ~~10~~ 18 square.

Step 4: ~~Split~~ Separate ~~into~~ (no) 2 groups (i.e. pair)
One student say a area, the other have to draw one rectangle that is pair. Check.

Finally: de brief: what have learnt?

Figure 3

28. Below are the cookies bought by Mrs. Chan.

What is the fraction of  shaped cookies in proportion to all the cookies bought?

29. Mrs. Chan ate $\frac{2}{9}$ of the cookies, and Mr. Chan ate $\frac{4}{9}$. What is the fraction of cookies left? (You must show your calculation.)

Figure 4

16. In the figure below, the length of each of the small square is 1 cm.

What is the area of the shaded figure?

Table 3 displays the results of systematic observations of the target pupils at the beginning and end of the implementation period. (i) Significant differences were found in group work setting, with the experimental pupils more likely to focus on their group mates (standardized adjusted residual [SAR] = 4.1) and the control pupils more likely to focus on the teacher (SAR = 4.9). (ii) The observations at the end of the school year produced even more extreme results in this regard, with the experimental pupils focusing on their group mates in 50.3% of observations (SAR = 7.5) and the control pupils focusing on the teacher in 66.9% (SAR = 6.9). (iii) In the initial observations, the experimental pupils were more attentive (listening/watching) and communicative (providing more information to group mates, explaining and disagreeing) in class compared to their control counterparts. (iv) In the end-of-school-year observations, the experimental children were more likely to maintain peer-based communicative interactions via non-verbal actions and to listen/watch, ask questions, make suggestions, give information, agree and maintain the group. Although the control pupils also engaged in such interactions, they did so less frequently and decreased their peer-based communicative interactions over time. (v) The on-/off-task observations initially showed the control children more likely to be off-task (SAR = 3.8) and the experimental children more likely to be on-task (SAR = 1.9), and these results widened in the end-of-year observations (control group: SAR = 5.5; experimental group: SAR = 6.8). (vi) Finally, observations of tasks undertaken by groups or individuals showed that the control children initially undertook their assigned tasks as individuals (SAR = 7.2), whereas their experimental counterparts did so both as individuals and as a group (SAR = 3.7) or only as a group (SAR = 6.6). The end-of-year observations again found that the control children undertook most tasks as individuals (SAR = 8.9), whereas the experimental children now did so either as individuals (SAR = 3.7) or as a group (SAR = 7.5).

Table 3

Observations of Target Pupil Actions and Interactions; Comparisons of Experimental and Control Pupils in Pre- and Post-Observations

Observation category	Pre-observation				Post-observation			
	Significant differences (X^2 , [df])	Frequency of observation		SAR+	Significant differences (X^2 , [df])	Frequency of observation		SAR+
		Exp	Con			Exp	Con	
Work setting	[5]27.82***				[5]=63.03***			
Non-verbal	NS	142	85		[1] 5.01*	145	66	2.2
Listening/watching	[1] 5.18*	260	170	2.3	[1] 14.28***	307	148	3.8
Questions	NS	8	2		[1] 4.85*	8	0	2.2
Suggestions	NS	18	6		[1] 23.78***	45	2	4.9
Gives information	[1]13.92***	145	63	3.7	[1] 19.83***	152	50	4.5
Explaining	[1] 9.32**	30	6	3.1	NS	26	10	
Agreeing	NS	19	6		[1] 8.37**	27	4	2.9
Disagreeing	[1] 9.59**	28	5	3.1	NS	19	6	
Seeking help	NS	9	9		NS	18	5	
Group maintenance	NS	23	9		[1] 8.93**	25	3	3.0
On/off-task	[2]19.02***				[2] 52.52***			
Group/ind. task	[2]65.01***				[2] 98.35***			

+Standardized adjusted residual: only significant SARs above 1.0 are reported

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

According to collaborative rationales for group work (e.g., Dillenbourg et al., 1996; Gillies, 2012; Reznitskaya et al., 2009), achievement within the classroom can be mediated by the quality of peer interactions, a possibility that was accounted for in this study by a composite interaction score (see section on Statistical Analyses). To examine the relationship between achievement and interaction quality, we used a two-step regression approach (Baron & Kenny, 1986). The first step involved simple regression analysis testing whether the quasi-experimental condition predicted achievement. The results showed the experimental pupils to have improved their level of achievement to a significantly higher degree than the control pupils ($b_1 = 3.40$, $p < 0.05$), garnering, on average, 3.40 more points in their post-test achievement scores. The second step explored whether the achievement gain could be explained by the composite interaction score. Conventional/single-level regression HLM analysis was performed using MPlus 7 (Muthén & Muthén, 2012), with the between-level

(composite) mediator placed in the second level for analysis of significance (Snijders & Bosker, 2012). The results showed the composite interaction (questioning, explaining, suggesting, time-on-task) score to mediate the achievement results to a significant degree ($\gamma_{11} = 0.54$, $p < 0.01$, indicating that, as achievement increased (in the experimental classes), the children were more likely to communicate collaboratively and to stay on-task.

Discussion

This quasi-experimental study assessed whether pupils' mathematics achievement can be enhanced by an effective group work program undertaken within a CHC in which high levels of mathematical understanding already exist. The study was relatively small in scale, but its implications for the teaching of mathematics (and other subjects) provide insight for the further enhancement of pupil learning via communicative engagement in classroom group work. It provides an approach that can be integrated with HK curriculum recommendations for a change in classroom pedagogy (CDCHK, 2001).

The matching of experimental and control teachers/classes, with random assignment to the intervention group, provided a nearly equal starting point for the study. Analyses provide statistically significant answers to the study's three research questions, the first two of which asked whether the experimental teachers could adapt, co-develop and apply the relational approach to group work in their P4 mathematics classes. Working with the researchers, the experimental teachers drew upon the relational guidelines for group work to jointly adapt a sequence of activities and problems for their classes. Based on several implementation scales, the experimental teachers promoted higher levels of group work than their control counterparts through their initial structuring of and continuing support for group work skills in their classes. The initial implementation scale results showed that both teacher groups had established a physical classroom set-up conducive to group work. However, the final scale results showed the experimental teachers to be more likely to encourage group

work that effectively supported pupils' achievement, and their pupils demonstrated more collaborative and supportive peer interactions.

Effects of the intervention were also seen in the systematic observations of classroom actions. The initial observations found the experimental pupils' focus of attention to be equally weighted between their group mates and the teacher/class as a whole, whereas the final observations showed that weighting to have altered in favor of the group (group:teacher focal ratio = 70:30). The control pupils' initial focus on group mates was limited (24%), with the teacher their main focus of attention (76%). The final observations recorded a slight shift toward group mates, although these pupils still maintained a strong teacher-oriented focal ratio (group:teacher = 40:60). Further, over the course of the study, the experimental teachers saw a significant rise in PEF, whereas that of the control teachers remained roughly the same. Data from the PEF measure, implementation scales and systematic classroom observations consistently showed the experimental teachers and their classes able to adopt and adapt group work methods based on the relational approach. Although exposed to substantial amounts of group work, the control teachers and their classes remained largely teacher-focused.

To explain the effect of adapting classrooms to encourage more group work, we draw upon Kennedy's (2010) assertion that, given appropriate support, CHC teachers are capable of change and of allowing their pupils to become more active and open learners (Cheng, 2000). The adaptability of HK CHC classrooms contrasts with the findings of Nguyen et al. (2006) in Vietnamese classrooms. In explanation, we note that the relational approach used in this study was culturally adapted (see Whitty et al., 1998) for classroom use by the experimental teachers.

Investigation of the third research question found the experimental pupils' mathematical achievement to be significantly enhanced by participation in the program, which is in line with previous SPRinG-based results (e.g., Kutnick & Blatchford, 2014), although the current study focused specifically on mathematics. The relational approach was not introduced by the

general class teacher, as in prior studies, but by specialist mathematics teachers who saw the experimental pupils for a limited amount of time each week (an average of one mathematics lesson per school day). The effect size in the achievement difference between the experimental and control classes was slightly smaller than that in previous SPRinG studies, possibly because of the shorter implementation period (just five to six months). Within the implementation period, the experimental pupils still demonstrated an approximately two-month gain in mathematics achievement over their control counterparts, suggesting that a significant threshold of difference was reached (Cooper & Dunne, 2000). Further, it should be noted that achievement effects of the relational intervention was likely to be found in many areas of the mathematics curriculum – including number sequences, patterns, fractions and area. The approach described in the study was not limited to any particular concepts within the HK P4 mathematics curriculum.

One of the key distinctions between this study and other randomized control studies of mathematical achievement via effective group work was our focus on child relationships rather than on teaching children to work in a cooperative manner or teaching them basic communicative/collaborative skills. Within the relational approach, there is a strong inclusive focus on developing a sense of trust and security among children, which contrasts with studies of collaborative (Reznitskaya et al., 2009; Yackel et al., 1991) and cooperative (Roseth et al., 2006; Slavin, 2013) learning that assume that pupils necessarily bring collaborative communication skills to the classroom, along with a desire to undertake joint learning tasks. Our relational focus allowed the child participants to develop more general communication skills (questioning, explaining, etc.) and to use them with greater frequency and to greater effect over the implementation period. Although the experimental pupils displayed greater improvements in interpersonal attention, support and communication than their control counterparts, a number of related actions and interactions need to be considered

simultaneously. It should be noted that the two pupil groups were equally naïve at the study's outset. According to Damon and Phelps (1989), peer-based communication is indicative of the mutual development of understanding, in contrast to expert/novice explanations for the development of understanding such as "scaffolding" (e.g., Topping et al., 2004). Mutual development necessarily places children in a position whereby the onus is on all children in the class to participate in furthering joint understanding. They are not necessarily assigned individual subtasks within a group (goal-based) task, as recommended by Slavin et al. (2013), and they cannot rely on others who are perceived to be more knowledgeable or powerful. An increase in children's degree of mutual interaction is also associated with more time spent "on-task," allowing children to maintain a focus on mathematics learning rather than being distracted by non-group and off-task talk (Emmer & Gerwels, 2002).

The teachers, too, were found to play a fundamental role in promoting pupils' enhanced mathematical achievement in this study. The experimental teachers were observed to become less didactic and more interactive during the study period. In the observations, these teachers were seen to offer more opportunities and more encouragement/support for pupils' engagement in group work over time. They demanded less pupil attention and became increasingly likely to interact with and support within-group discussions (see Gillies, 2012; Webb et al., 2014). The experimental teachers also achieved gains in mathematical pedagogic efficacy.

Conclusion and Limitations

In contrast to several recent randomized controlled studies in the primary school mathematics context (e.g., Slavin et al., 2013; The Metiri Group, 2009), this study found significant achievement effects, as well as associated developments in pupils' on-task focus and communicative (collaborative) interactions and teachers' pedagogic efficacy. The differences between this and previous studies lie in three areas: context, approach and size (the latter of which we acknowledge as a limitation below). First, this study was undertaken in HK, where

contextual and international comparisons have consistently found high levels of mathematical understanding among primary and secondary students (Mullis et al., 2012; OECD, 2010), particularly in relation to their English and American counterparts. Second, much of this achievement has been attributed to the traditional didactic mathematics teaching approach that prevails in CHC classrooms such as those in HK. The experimental teachers in the current study had to overcome the non-group work-oriented (CHC) approach that they would more commonly use. The changes seen in the relationship between these teachers and their pupils can be credited to the culturally appropriate pedagogy adopted (Whitty et al., 1998), which allowed teachers to work within and adapt relational elements to foster the increased pupil and teacher engagement recommended in the HK mathematics curriculum (CDCHK, 2000). Further, different from previous studies on learning cooperation and collaboration, the results of this study support the use of an approach that problematizes initial in-class peer relationships, provides supportive training for classroom learning to take place in an inclusive manner and does not focus on a singular aspect of the mathematics curriculum (see Baines et al., 2009).

Finally, with regard to size, although we acknowledge that our sample size was relatively small compared with international studies in this arena, it was sufficiently large for HLM analysis. A larger and more representative sample would, however, have rendered our conclusions more generalizable. Future studies may also consider how pupils' development of relational skills facilitates their use of elaborated communication (explanations, justifications, etc.) and how those skills are brought to fruition in mathematical discussions, thereby pinpointing the causal factors underlying specific aspects of their enhanced mathematics achievement. Such studies would necessarily draw upon qualitative methods to complement larger-scale, quasi-experimental research.

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